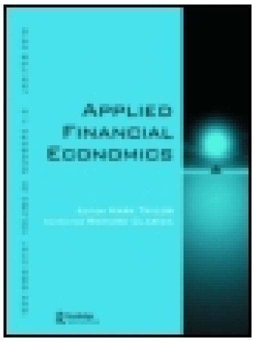

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Short- and long-term links among European and US stock markets

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Short- and long-term links among European and US stock markets

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Recently, national economies have become more internationalized because of increased trade and increased cooperation between national governments leading to removal of barriers to free flow of goods and services, and financial, physical and human capital. The relationship between equity markets in various countries has been examined extensively in the literature. This study tests the interdependence between stock prices in Germany, the UK, the Netherlands and the US, using daily closing prices for the period between March 1990 and October 1994. Results of the tests show that the US exerts a significant impact on European markets. Moreover, the three European markets influence each other in the short and long run. Therefore, diversification among these national stock markets will not greatly reduce the portfolio risk without sacrificing the expected return.

I. INTRODUCTION

In the last 30 years there has been an increase in diversification at several levels in the world economy. Large firms have discovered advantages in international diversification and have diversified direct investments geographically and across industries to become today's multinational corporations. Smaller investors and professional investment and pension fund managers who look after their interests, have also become aware of the potential benefits of international diversification. Cross-border investment continues its rapid worldwide growth as investors are attracted by the potential opportunities for increased returns and diversification benefits to be gained from an international approach to investment. In response to this phenomenon, banks and financial institutions have increased the number of international products and services they offer, while organized financial markets have tried to cope by adjusting products, procedures and trading times. Due to financial deregulation and advances in computer technology, world stock markets have become more integrated. The globalization of markets and economies has resulted in stronger linkages between the markets of the world.

However, at the heart of the concept of international diversification is the notion that economic conditions and shareholders' returns in different (domestic and foreign) markets are less than perfectly correlated. If this is indeed the case, it is possible to reduce portfolio risk without sacrificing expected return by selecting individual securities in such a way that their risk characteristics offset each other.

In this paper we use a vector error correction model to examine long-term links and short-run causality for four different capital markets.

II. PREVIOUS STUDIES

Recently, national economies have become more internationalized because of increased trade and improved cooperation between national governments leading to the removal of barriers to free flow of goods, services, and financial, physical and human capital. The relationships between equity markets in various countries have been extensively examined in many previous empirical studies. However, many early studies have made a strong case for international portfolio diversification. The benefits of international diversification have been documented. Such diversification allows reduction of the total risk of a portfolio while enhancing the performance opportunities.

The lack of interdependence across national stock markets has been presented as evidence supporting the benefits of international portfolio diversification. Agmon (1972), using weekly or monthly return data, finds no significant leads or lags among the common stocks of Germany, Japan, the

UK and the USA. Studies, such as Lessard (1976) and Jorion and Schwartz (1986), using regression models to test for the existence but not the degree of market segmentation, suggest that market segmentation does exist in some national equity markets.

The stock market crash of 1987 provided new insights into the economic nature of globalization of stock markets. Dwyer and Hafer (1988), using daily data for seven months before and after the October 1987 crach, show no evidence that the levels of stock price indices for the US, Japan, Germany and the UK are related. They report statistical evidence, however, that the changes in the stock price indices in these four markets are generally related.

More recent studies, however, examining the stock price indices around the stock market crash of 1987 by Eun and Shim (1989). Von Furstenberg and Jeon (1989), and Bertera and Mayer (1990) report a substantial amount of interdependence among national stock markets.

Many studies have been made to examine the international linkage between the US and Japan. Becker *et al.* (1990), Hamao *et al.* (1990), Kasa (1992) find strong correlation between the two markets with an asymmetric spillover effect from the US to the Japanese market, while Smith *et al.* (1993) and Aggerwal and Park (1994) find that US equity prices do not lead Japanese equity prices and state that gains from international diversification are obtainable.

Recently, considerable attention has been given to possible linkages and interdependencies in major Asian countries. Lee *et al.* (1990), Chan *et al.* (1992), Chowdhury (1994), Rogers (1994) and Kwan *et al.* (1995), using cointegration tests and vector autoregression analyses, report that international diversification in those countries can be effective.

European countries are also frequently examined for interdependencies between stock exchange markets. Mathur and Subrahmanyam (1990), Arshanpalli and Doukas (1993), and Malliaris and Urrutia (1992) have used the concept of Granger causality, and cointegration and error-correction models to analyse the linkages and dynamic interactions among stock prices.

Taylor and Tonks (1989) examine the impact of the abolition of UK exchange control on the degree of integration of UK and overseas stock markets. The authors use monthly stock market index data from the following five stock markets: United Kingdom, West Germany, Netherlands, Japan and the United States. They test short-run causality and cointegration relationships among these markets in two subperiods: April 1973 to September 1979 and October 1979 to June 1986. According to their results all markets are integrated of order 1. The cointegration tests indicate the existence of cointegration between the UK, West Germany, Netherlands and Japan post-1979, but not before. According to the Granger causality tests causality runs from the UK to the German, Dutch and Japanese markets and from Germany to the Netherlands, from Japan to Germany, and from Japan to the Netherlands. No significant causality is deduced in any pair involving the United States. The authors conclude that the benefits from international diversification will be reduced in the long run.

The literature review has shown that there is conflicting evidence for possible international stock market linkages. Hence this subject needs further investigation. In this paper, the linkages among stock prices in the stock exchanges of Germany, Holland, the UK and the US are studied, using daily closing data from March 1990 through October 1994. Cointegration tests and a vector error correction model, VEC, are used for the analysis of a possible existence of short- and long-term linkages among the equity markets.

III. DATA AND METHODOLOGY

The data used to investigate short-run and long-run interdependencies consist of the daily closing prices for the following equity market indexes: London (FTSE 100 Price Index – FTSE 100), Frankfurt DAX, Amsterdam EOE, and New York (Dow Jones Industrial Average – DJIA). Daily closing data for all four indices have been collected for the period beginning 1 March 1990 and ending 5 October 1994. The sample consists of 1188 observations. When national stock exchanges were closed due to national holidays, bank holidays or severe weather conditions, the index level was assumed to remain the same as that on the previous trading day.

The *Financial Times* – Stock Exchange 100 Share (FTSE 100) Index represents 70% of the equity capitalization of all United Kingdom equities. The Amsterdam European Options Exchange (EOE) Index consists of 25 shares, representing 88% of the total market while the Deutsche Aktien Index (DAX) in Frankfurt (consisting of 30 shares) represents 60% of the equity capitalization of all German Equities. The Dow Jones Industrial Average (DJIA), however, is the average of 30 stocks in the NYSE, and represents only 22–25% of the total market.

In this study, the methodology we use for common trends in international stock markets is based on the vector error correction model, VEC. The first step in examining trends in international stock markets is to test for stationarity of the time series. The time series properties of each series are investigated using Augmented Dickey–Fuller and Phillips–Perron tests.

The methodology used to examine short- and long-term linkages among equity markets, is the vector error correction model, VEC. The VEC model is based on the concept of causality in the Granger sense and on the notion of cointegration.

(*a*) *Granger causality tests*

Granger causality tests are used to examine causality in time series models. A series X_t causes another series Y_t if it is seen that the series X_t has information helping to characterize future Ys that is unique. More specifically, X is said to cause Y if a coefficient a_i is not zero in the following equation:

$$Y_t = C_0 + \sum_{i=1}^{m} a_i X_{t-i} + \sum_{j=1}^{m} b_j Y_{t-j} + e_t \quad (1)$$

Similarly, Y is said to cause X if some coefficient α_i is not zero in Equation 2:

$$X_t = \Phi_0 + \sum_{i=1}^{m} \alpha_i Y_{t-i} + \sum_{j=1}^{m} \beta_j X_{t-j} + \mu_t \quad (2)$$

If X causes Y and also Y causes X, then there is said to be feedback. The test for causality is based on an F-statistic that is computed by running the above regressions in both unconstrained (full model) and constrained (reduced model) forms:

$$F = \left[\frac{(SSE_r - SSE_f)}{m} \right] \Big/ \left[\frac{SSE_f}{T - 2m - 1} \right] \quad (3)$$

where SSE_r and SSE_f are the sum of squares of the residuals of the reduced model and full model, respectively, and m the number of lags and T the number of observations.

(*b*) *Cointegration tests*

Although individual series that contain stochastic trends are nonstationary in their levels, if the stochastic trends are common across series there will be stationary linear combinations of the levels. This phenomenon is known as cointegration.

A process X_t is said to be an integrated process, if it is generated by an equation of the form

$$a_p(B)(1 - B)^d Xt = b_q(B)e_t \quad (4)$$

where e_t is zero-mean white noise, $a(B)$, $b(B)$ are polynomials in B of orders p and q, respectively ($a(B)$ being a stationary operator), and d is an integer. Such a process will be denoted $X_t \sim \text{ARIMA}(p, d, q)$ (autoregressive integrated moving average of order p, d, q) or $X_t \sim \text{I}(d)$. If X_t and Y_t are a pair of $\text{I}(d)$ series, then it will be generally true that a linear combination, such as

$$Z_t = X_t - AY_t \quad (5)$$

will also be $I(d)$. However, it can happen that there exists a constant A such that $Z_t \sim \text{I}(d - b)$, $b > 0$. When this happens, the pair of variables X_t and Y_t are said to be cointegrated and denoted $(X_t, Y_t) \sim \text{CI}(d, b)$. When $d = b = 1$ and there exists an A such that $Z_t = X_t - AY_t$ is stationary, i.e. $Z_t \sim \text{I}(0)$ then it means that both series individually have extremely important long-run components, but that in forming Z_t these long-run components cancel out and vanish. Z_t can now be interpreted as the equilibrium error, that is, the extent to which the economy is out of equilibrium. Engle and Granger (1987) suggest estimating the value of A by running the regression:

$$X_t = \gamma + AY_t + \varepsilon_t \quad (6)$$

We can then calculate the values of Z_t.

If two time series produce a stationary trend, then there exists an error correction representation, which suggest that one stock price index can be used to forecast the other. In other words, the existence of cointegration between two stock price indices implies that either one or both markets are inefficient.

(*c*) *Vector error correction model, VEC*

By combining the causality and cointegration test it is possible to develop a model that allows one to test for both short-term and long-term relationships between the series X_t and Y_t: the vector error correction model (VEC):

$$Y_t - Y_{t-1} = a_0 + a_1 \hat{Z}_{t-1} + \sum_{i=1}^{m} c_i (X_{t-i} - X_{t-i-1}) + \sum_{j=1}^{m} d_j (Y_{t-j} - Y_{t-j-1}) + \varepsilon_t \quad (7)$$

where $\hat{Z}_{t-1} = X_{t-1} - AY_{t-1}$.

The potential long-run and short-run impact of the series X on the series Y are, in the VEC model, decomposed as follows:

- A long-run component, represented by the cointegration term $a_i \hat{Z}_{t-1}$, also known as the error-correction term. The correction adjustments of Y_t to a disequilibrium error from the previous period Z_{t-1} can spread over several periods of time, with the coefficient a_1 indicating the speed of the correction mechanism.
- A short-run component, given by the summation terms in the right-hand side of Equation 7. These two terms represent past changes in the variables X and Y and characterize the short-run dyamics. Specifically, the first summation term in Equation 7 gives the short-run impact of X on Y.

Similarly, the potential long-run and short-run impact of the series Y on the series X can be expressed in the VEC model with a similar formula.

- The series X_t and Y_t are cointegrated when at least one of the coefficients of Z_{t-1} is different from zero. In this case, X_t and Y_t exhibit long-run comovements.
- There is a short-term relationship between the series X_t and Y_t when at least one of the coefficients of c_i is different from zero.

The error correction model has the standard interpretation: the change in X_t is due to the immediate, short-run effect of the change in Y_t and to last period's error, Z_{t-1}, which represents the long-run adjustment to past disequilibrium. Hence, estimation of the error-correction equations is also expected to provide evidence about the long-run relationship and the nature of the adjustment process among national stock markets. Furthermore, the error-correction analysis is fundamental for testing the cross-border market efficiency hypothesis since it describes the long-run dynamic adjustment process between two stock exchange markets.

IV. RESULTS AND INTERPRETATION

The autocorrelations in all four series do not die out gradually indicating the possibility of a unit root, and nonstationarity. After running both Dickey–Fuller and Phillips–Perron unit root tests on the natural logarithmic transformed data the results obtained are summarized in Table 1. All series exhibit trend components as can be seen from Figs 1–4. Therefore we check unit root in series with a null hypothesis as follows:

$H_0: X_t$ is a random walk plus drift around a stochastic trend.

We cannot reject the presence of a unit root in the level series, which indicates nonstationarity in all the time series. Next we check if the time series are integrated of order one by searching for a unit root in the difference series.

After running Dickey–Fuller and Phillips–Perron tests on the differenced natural logarithmic transformed data, the results obtained are as summarized in Table 2.

The null hypothesis of a unit root in first differences of the stock price indices is rejected for all four stock price index series. Comparing these values with the critical values, it is apparent that we can reject the hypothesis of nonstationarity for the differenced $\ln(X)$ data ($d\ln(X)$ data) at the 10% level. Therefore, we can conclude that the differenced natural logarithmic transformations of all market indices are stationary indicating that all the national stock index series are individually integrated of order one. The basic statistical properties for all four stationary time series, the differenced natural logarithmic is transformations, are given in Table 3.

The table shows that all of these series are leptokurtic. All series except FT exhibit negative skewness. These results are consistent with the literature that return series in various stock markets exhibit leptokurtosism and negative skewness.

Next we examine whether the national stock market index series are cointegrated. To check the cointegration relation, we again use Phillips–Perron and Dickey–Fuller tests on the residuals of cointegrating regressions. The residuals do not exhibit any trend therefore we report the results

Table 1. *Summary of Dickey–Fuller and Phillips–Perron tests*

	Dickey–Fuller test statistic	Phillips–Perron test statistic
$\ln(AEX)$	− 3.0430	− 1.9164
$\ln(DJ)$	− 2.8425	− 3.1236
$\ln(FT)$	− 2.4673	− 2.5977
$\ln(DAX)$	− 2.2050	− 2.2431
Critical values at 10% level	− 3.13	− 3.13

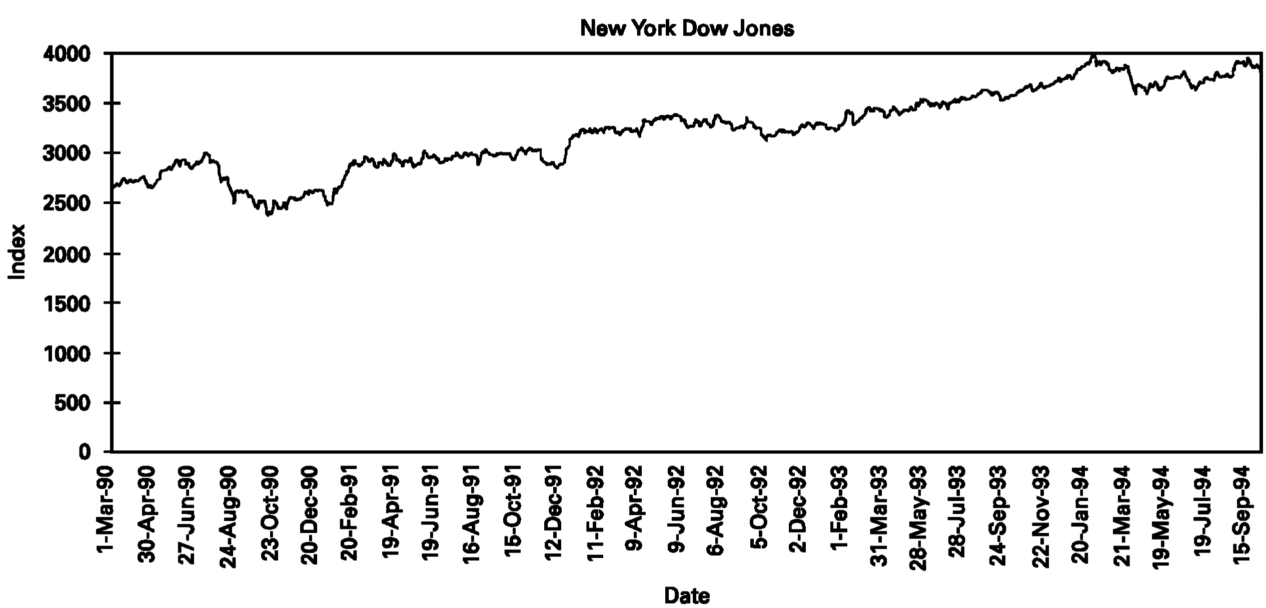

Fig. 1. *Daily closing prices of New York DJIA, 01/03/90–05/10/94*

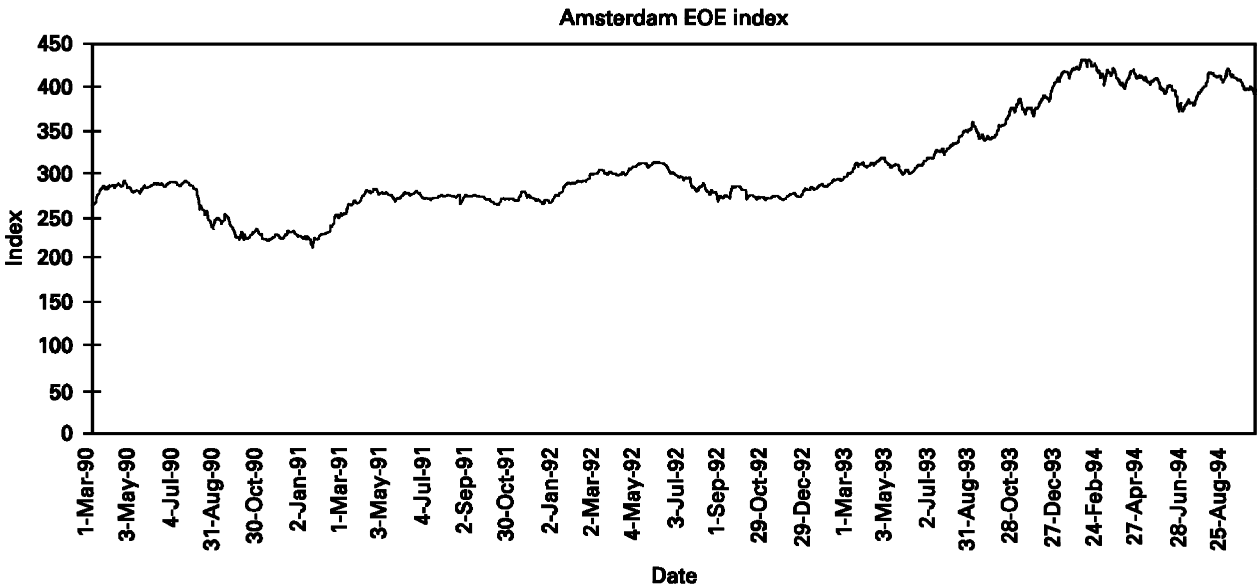

Fig. 2. *Daily closing prices of Amsterdam EOE, 01/03/90–05/10/94*

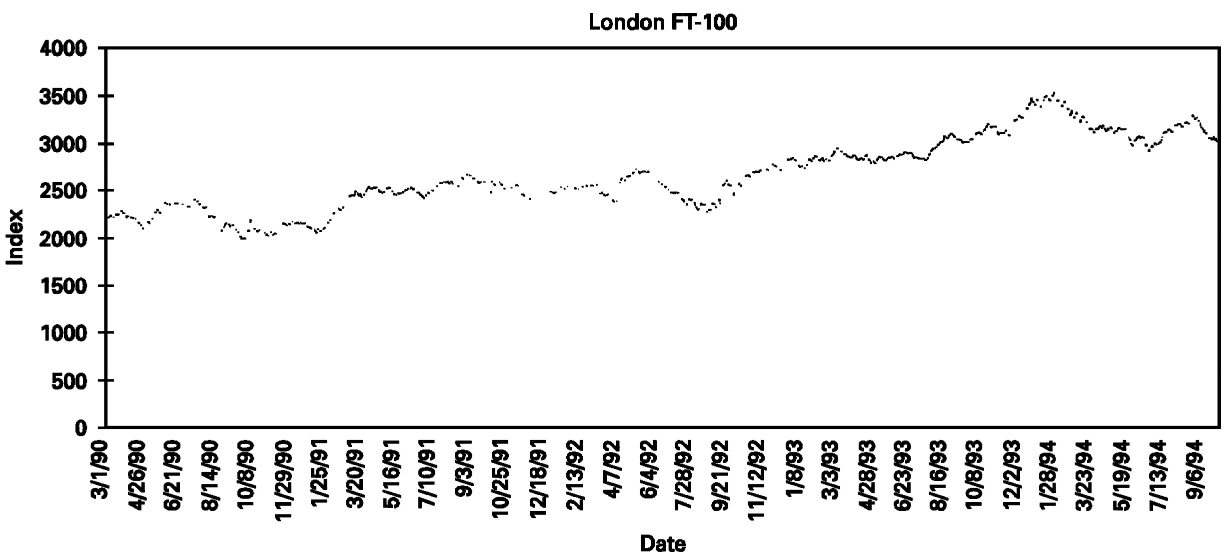

Fig. 3. *Daily closing prices of London FT*, *01/03/90–05/10/94*

of the following null hypothesis:

$$X_t = a + bY_t + u_t \qquad (8)$$

Ho: u_t is a random walk with no stochastic trend.

The results of the pairwise cointegration tests of stock market indices are presented in Tables 4 and 5.

Several interesting observations emerge when we look at the results in Tables 4 and 5. First, the results from the entire sample show that the stock markets of the Netherlands and Germany, and the US and the UK appear to be cointegrated. However, the null hypothesis of no cointegration between the other pairs of stock markets cannot be rejected. At the 5% level, the critical value of the DF statistic is 3.37. These results suggest that the link among stock prices in those pairs of stock exchanges has been very weak over the period.

Phillips–Perron and Dickey–Fuller tests give conflicting results in the case of UK and US markets. Therefore cointegration relationships among markets need further investigation. We use Granger causality tests for this. Next we examine both the cointegration relations and the short-run causality relationships among these markets by estimating the error correction equations. The term Z_{t-1} used in the error correction regressions was obtained from OLS

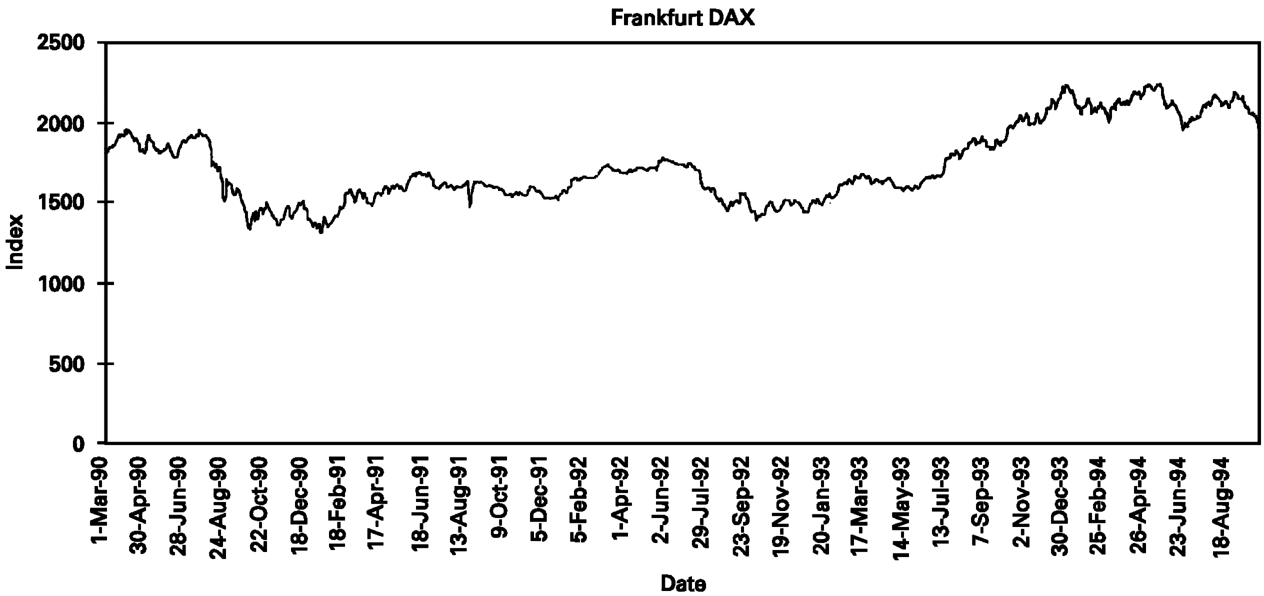

Fig. 4. *Daily closing prices of Frankfurt DAX, 01/03/90–05/10/94*

Table 2. *Summary of Dickey–Fuller and Phillips–Perron tests on differenced data*

	Dickey–Fuller test statistic	Phillips–Perron test statistic
$d\mathrm{Ln}(AEX)$	− 4.9818*	− 33.773*
$d\mathrm{Ln}(DJ)$	− 5.4618*	− 32.680*
$d\mathrm{Ln}(FT)$	− 6.3028*	− 33.191*
$d\mathrm{Ln}(DAX)$	− 5.2322*	− 33.394*

The asterisks indicate significance at the 5% level.

estimation of the cointegration equations. The result of the error correction equations are reported in Table 6.

The t-ratio for the coefficient of the error-correction term, Z_{t-1}, indicates a long-run relationship when the t-value is significant. This result implies that the equilibrium error can be used to predict next period's stock market price changes in either stock exchange. Another interesting aspect of the error correction analysis is that it yields information about the 'short-run' influence of the change in one market on the performance of another market.

The results (Table 6) indicate that the New York stock exchange affects the other stock exchanges, but not vice versa. The London stock exchange is influenced by Amsterdam, New York and Frankfurt stock exchanges. Moreover, Frankfurt is influenced by the stock markets of Amsterdam, New York and London, while short-term changes in the stock markets in Holland and the US have a substantial impact on the British stock market. However, none of the European markets influences the stock exchange of New York. Although the short-run influences from changes in one of the European markets on one of the other European markets are not as substantial as in the case of the US on the three European markets, they are significant. In the case of the two pairs of national markets, the earlier reported test did not indicate significant cointegration.

Tables 4 and 5 show that the stock markets of the Netherlands and Germany, and the US and the UK are cointegrated. Table 6 also reports that Amsterdam has a significant impact on the German stock market in the long run and therefore the two tests agree on the result. The results in Table 6 report significant impact of the US on the three European markets in the short and long run for the period examined. In all regressions reported in Table 6, the results show that the US market experts, in particular, a substantial influence in the short run (with F-values of 22.56, 13.84 and 19.44) on Amsterdam, London, and Frankfurt, respectively. However, other tests have reported no significant cointegration between US and European markets. In contrast, European 'short- and long-run' stock market changes do not appear to have any significant impact on the US stock market. This result is inconsistent with the view that foreign stock market innovations have exerted substantial influence on the US market in the post-October 1987 period.

Taylor and Tonks (1989) report a cointegration relationship between the UK and West Germany, between the UK and the Netherlands, and no cointegration relationship between the US and the UK in the post-1979 period. Our analysis shows that after 1990 there is a cointegration relationship only between Germany and the Netherlands. Our results also indicate that after 1990 cointegration relationships between the UK and other European markets vanished. Short-run causality tests indicate that the influence of the New York stock exchange on the others has increased

Table 3. *Statistical properties of* $d\ln(X)$ *data*

	DAX	*AEX*	*FT*	*DJ*
N	1187	1187	1187	1187
Sum Wgts	1187	1187	1187	1187
Mean	0.000268	0.000269	0.000347	0.000391
Sum	0.388445	0.932806	0.505753	0.568692
Std Dev.	0.011863	0.008962	0.008515	0.008111
Variance	0.000141	0.00008	0.000073	0.000066
Skewness	− 1.0798	− 0.60812	0.188037	− 0.48118
Kurtosis	16.72381	4.997861	2.289167	6.291457

Table 4. *Cointegration test, Dickey–Fuller: Constant, no trend (10% critical value = − 3.04)*

	ln *AEX*	ln *DJ*	ln *FT*	ln *DAX*
ln *AEX*		− 2.2893	− 1.7536	− 2.7463
ln *DJ*	− 2.5833		− 2.5973	− 2.4034
ln *FT*	− 2.1856	− 2.8910		− 2.3049
ln *DAX*	− 3.1790*	− 2.6983	− 2.1962	

The asterisks indicate significance at the 5% level.

Table 5. *Cointegration test, Phillips–Perron: Constant, no trend (10% critical value = − 3.04)*

	ln *AEX*	ln *DJ*	ln *FT*	ln *DAX*
ln *AEX*		− 2.4751	− 1.8388	− 2.8534
ln *DJ*	− 2.7767		− 3.2214*	− 2.4313
ln *FT*	− 2.1950	− 3.2290*		− 2.1718
ln *DAX*	− 3.1473*	− 2.4033	− 2.1765	

The asterisks indicate significance at the 5% level.

and the influence of the London stock exchange has decreased since 1986. There is a feedback relationship between London and Frankfurt stock exchanges.

V. CONCLUSION

The theory of causality and the notion of cointegration are used to examine linkages and dynamic interactions among stock price indices in four stock exchanges (Amsterdam, London, New York and Frankfurt) by means of the error-correction model. The data used in this study are daily closing prices of the stock exchanges. The sample consists of 1188 observations and covers the period March 1990 through October 1994.

Tests of stationarity allow us to conclude that the level series are nonstationary, but the difference series are stationary. Thus, prices are integrated of order one, I(1) and the use of the vector error correction model is appropriate to test for long- and short-run interdependencies between the four stock exchanges. The error-correction analysis produced some interesting results with respect to the stock market interactions among the four stock exchanges.

The US market exerts a significant long-term impact on the European markets, but not vice versa. Moreover, the US stock price index variable has a substantial amount of short-term influence on all other markets. This result is inconsistent with the view that foreign stock market innovations have exerted substantial influence on the US market in the post-October 1987 period.

The three European markets also influence each other in the short and long run. This result implies that these markets are not independent from each other but move together. This can be explained by the fact that the three countries are members of the European Union. The implementation of some institutional agreements of the European Union concerning equity markets, the exchange rate mechanism that is partly coordinated among the countries, and

Table 6. *Error correction results*

Dependent	Independent	*a*1	*c*1	*c*2	*c*3	*c*4	*c*5	F-statistics
Amsterdam	New York	0.0098820 (2.137)*	0.34502 (10.44)*	− 0.02914 (− 0.8438)	− 0.0090465 (− 0.2627)	− 0.016242 (− 0.4713)	0.027779 (0.8064)	22.56*
Amsterdam	London	0.011936 (2.623)*	0.061702 (1.594)	− 0.049239 (− 1.273)	− 0.053930 (− 1.392)	0.055249 (1.422)	0.023224 (0.6007)	1.60
Amsterdam	Frankfurt	− 0.0061874 (− 1.376)	− 0.012375 (− 0.4021)	− 0.047940 (− 1.557)	− 0.039921 (− 1.293)	0.0059092 (0.1915)	0.070494 (2.3)	1.88
New York	Amsterdam	0.0019028 (0.6048)	− 0.029687 (− 1.021)	0.021912 (0.7536)	− 0.031171 (− 1.073)	0.043805 (1.509)	− 0.013466 (− 0.4845)	1.19
New York	London	0.0070113 (1.438)	− 0.023246 (− 0.7979)	0.015819 (0.5437)	− 0.026887 (− 0.9244)	0.025744 (0.8837)	− 0.015573 (− 0.5480)	0.62
New York	Frankfurt	− 0.0009045 (− 0.3829)	− 0.02804 (− 1.301)	− 0.013071 (− 0.6062)	− 0.041089 (− 1.908)	0.042424 (1.971)*	0.0048392 (0.2325)	2.00
London	Amsterdam	− 0.0025920 (− 0.7455)	− 0.13412 (− 3.630)*	0.014007 (0.377)	0.038064 (1.028)	0.099497 (2.687)*	− 0.04077 (− 1.098)	4.51*
London	New York	0.0099255 (1.774)	0.26916 (8.153)*	− 0.02673 (− 0.7878)	− 0.0047266 (− 0.1398)	0.046485 (1.373)	0.31116 (0.9187)	13.84*
London	Frankfurt	− 0.0044224 (− 1.655)	− 0.17546 (− 0.7173)	− 0.015492 (− 0.6343)	− 0.0007177 (− 0.029)	0.069911 (2.866)*	0.035315 (1.46)	2.22*
Frankfurt	Amsterdam	0.011687 (2.616)*	0.16706 (3.156)*	0.13692 (0.2576)	0.045934 (0.8639)	0.028769 (0.5426)	− 0.062235 (− 1.176)	2.47*
Frankfurt	New York	0.0072836 (2.085)*	0.40184 (9.318)*	− 0.095089 (− 2.132)*	0.0574475 (1.289)	0.031750 (0.7113)	0.052671 (1.180)	19.44*
Frankfurt	London	0.0087218 (2.544)*	0.22609 (5.271)*	− 0.070569 (− 1.633)	− 0.076671 (− 1.770)	0.053094 (1.223)	− 0.19565 (− 0.4506)	7.09*

The *t*-ratios are given in parentheses. The asterisks indicates significance at the 5% level. The joint significance of the indicates is determined by the standard F-test.

intensive trade and other cooperation between the national governments have removed many barriers and resulted in a high degree of integration. As a result, the markets have been globalized. Previous studies have made a strong case for international portfolio diversification to reduce the risk of a portfolio while enhancing the performance opportunities. However, the condition that national stock markets lack interdependence is rejected for the examined stock exchanges because of significant reported short- and long-term linkages. Therefore, diversification among these national stock markets will not greatly reduce the portfolio risk without sacrificing expected return.

In future we shall include other stock market data in our analysis to examine the relationships among different European markets and also among European markets and Asian markets (Japan, Hong Kong...).

REFERENCES

Aggerwal, R. and Park, Y. S. (1994) The relationship between daily US and Japanese equity prices: Evidence from spot versus futures markets, *Journal of Banking and Finance*, **18**, 757–73.

Agmon, T. (1972) The relations between equity markets: A study of share price co-movements in the United States, United Kingdom, Germany, and Japan, *Journal of Finance*, **27**, 839–55.

Arshanapalli, B. and Doukas, J. (1993) International stock market linkages: Evidence from the pre- and post-October 1987 period, *Journal of Banking and Finance*, **17**, 193–208.

Becker, K. G., Finnerty, J. E. and Gupta, M. (1990) The intertemporal relation between the US and Japanese stock markets, *Journal of Finance*, **45**, 1297–306.

Bertera, E. and Mayer, C. (1990) Structure and performance: Global interdependence of stock markets around the crash of 1987, *European Economic Review*, **34**, 1155–80.

Chan, K. C., Gup, B. E. and Pan, M. S. (1992) An empirical analysis of stock prices in major Asian markets and the United States, *The Financial Review*, **27**, 289–307.

Chowdhury, A. R. (1994) Stock market interdependencies: Evidence from the Asian NIEs, *Journal of Macroeconomics*, **16**, 629–51.

Dwyer, G. P. and Hafer, R. W. (1988) Are national stock markets linked?, *Federal Reserve Bank of St. Louis Review*, **70**, 3–14.

Engle, R. F. and Granger, C. W. (1987) Co-integration and error correction: representation, estimation, and testing, *Econometrica*, **55**, 251–76.

Eun, C. S. and Shim, S. (1989) International transmission of stock market movements, *Journal of Financial and Quantitative Analysis*, **24**, 241–56.

Hamao, Y., Masulis, R. W. and Ng, V. (1990) Correlations in price changes and volatility across international stock markets, *The Review of Financial Studies*, **3**, 281–307.

Jorion, P. and Schwartz, E. (1986) Integration versus segmentation in the Candian stock market, *Journal of Finance*, **41**, 603–16.

Kasa, K. (1992) Common stochastic trends in international stock markets, *Journal of Monetary Economics*, **29**, 95–124.

Kwan, A. C. C., Sim, A. B. and Cotsomitis, J. A. (1995) The causal relationships between equity indices on world exchanges, *Applied Economics*, **27**, 33–7.

Lee, I., Petitt, R. and Swankoski, M. V. (1990) Daily return relationships among Asian stock markets, *Journal of Business Finance and Accounting*, **17**, 265–84.

Lessard, D. A. (1976) International diversification, *Financial Analyst Journal*, **32**, 32–8.

Malliaris, A. G. and Urrita, J. (1992) The international crash of October 1987; causality tests, *Journal of Finance and Quantitative Analysis*, **27**, 353–64.

Mathur, I. and Subrahmanyam, V. (1990) Interdependencies among the Nordic and US stock markets, *Scandinavian Journal of Economics*, **4**, 587–97.

Rogers, J. H. (1994) Entry barriers and price movements between major and emerging stock markets, *Journal of Macroeconomics*, **16**, 221–41.

Smith, K. L., Brocato, J. and Rogers, J. E. (1993) Regularities in the data between major equity markets: evidence from Granger causality tests, *Applied Financial Economics*, **3**, 55–60.

Taylor, M. P. and Tonks, I. (1989) The internationalisation of stock markets and the abolition of the U.K. Exchange Control, *The Review of Economics and Statistics*, **71**, 332–6.

Von Furstenberg, G. M. and Jeon, B. N. (1990) Growing international comovements in stock price indexes, *Quarterly Review of Economics and Business*, **30**, 15–30.